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Comments on the taxonomic treatment of *Arisaema* (Araceae) in Flora of China

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The taxonomic treatment of *Arisaema* (Araceae) in China in volume 23 of the *Flora of China* (FOC) in 2010 recognized 78 species in 12 sections. The circumscription of the sections was revised by Murata in 2011 and the names of the sections were reviewed more recently by Murata *et al*. in 2013. In the FOC the circumscription of some species was changed drastically and four new species were described. Notes on the treatment in the FOC are given, based on recent cytological and molecular data, according to the sections recognized by Murata *et al*. in 2013.

Key words: *Arisaema*, Flora of China, systematics, taxonomy

Arisaema (Araceae) consists of about 180 species occurring mainly in warm temperate and subtropical regions from Asia westward to NE Africa, southward to Indonesia, eastward to Japan and also in North America. The largest center of diversity is in China. The taxonomic treatment of *Arisaema* in China, published in volume 23 of the *Flora of China* (FOC) (Li *et al*. 2010) recognized 78 species in 12 sections. In the FOC treatment the circumscriptions of some species were drastically changed and four new species were described.

The sections of *Arisaema* were revised by Murata (2011) and the names of the sections were reviewed more recently in Murata *et al*. (2013). Here, notes on the treatment in the FOC, in considering recent cytological and molecular data, are given according to the sections recognized in Murata *et al*. (2013). For a better understanding of the taxonomic history of *Arisaema* in China, differences in four recent major publications are summarized in Table 1.

In compiling the manuscript for the FOC, the authors did not agree on the nomenclature and circumscription of some species. In the FOC such species are supplemented with a note on the authors' points of contention, which are not repeated here.

Materials and methods

Morphology and ecology: Living plants of *Arisaema* were observed in the field in China (mainly in Yunnan), where herbarium specimens and samples for chromosome observations and DNA analysis were collected. Specimens in the herbaria of A, BKF, BM, CUL, K, KYO, KUN, NY, P, PE, TI and W were also examined.

Chromosome observations: Root tips removed from living specimens were used for observing somatic chromosomes. The root tips were pretreated with water at 0°C for 24 hours, and

TABLE 1. Difference in the treatment of Chinese *Arisaema*. Species are arranged basically in the alphabetical order of the sections recognized by Murata (2011, 2013).
Abbreviation of section name: Ano=Anomala, Ari=Arisaema, Att=Attenuata, Cla=Clavata, Dec=Decipientia, Do=Dochafa, Ex=Exappendiculata, Fim.=Fimbriata, Fra=Franchetiana, Lob=Lobata, Nep=Nepentoidea, Odo=Odorata, Pis=Pistillata, Sin=Sinarisaema, Ten=Tenuipistillata, Tor=Tortuosa.
Synonyms are shown in parenthesis. nt: not treated. *: probably based on misidentification. **: Murata(2011) did not cite synonyms.

FRPS (1979)		Gusman & Gusman (2006)		FOC (2010)		Murata (2011)	
Species	Section	Species	Section	Species	Section	Species**	Section
nt		*bannaense*	Ano	*bannaense*	Ano	*bannaense*	Ano
grapsospadix	Fim	*grapsospadix*	Ano	*grapsospadix*	Ano	*grapsospadix*	Ano
hainanense	Ari	*hainanense*	Ano	*hainanense*	Ano	*hainanense*	Ano
nt		*lihengianum*	Ano	*lihengianum*	Ano	*lihengianum*	Ano
nt		*menglaense*	Ano	*menglaense*	Ano	*menglaense*	Ano
nt		*petelotii*	Ano	*petelotii*	Ano	*petelotii*	Ano
inkiangense	Fim	*inkiangense*	Ano	*petiolulatum*	Ano	*petiolulatum*	Ano
nt		*pingbianense*	Ano	*pingbianense*	Ano	*pingbianense*	Ano
calcareum	Fim	*calcareum*	Ano	*rubrirhizomatum*	Ano	*rubrirhizomatum*	Ano
nt		sp. *'Tsangpo'*	Ano	*smitinandii*	Ano	*tsangpoense*	Ano
nt		*victoriae*	Ano	*victoriae*	Ano	*victoriae*	Ano
asperatum	Tri	*asperatum*	Ari	*asperatum*	Ari	*asperatum*	Ari
bonatianum	Tri	nt		*bonatianum*	Ari	*bonatianum*	Ari
**griffithii* (*salwinense*)	Tri	**griffithii* (*salwinense*)	Ari	(*bonatianum*)			
smithii	Tri	(*wilsonii*)		(*bonatianum*)			
nt		nt		*brucei*	Ari	*brucei*	Ari
costatum	Tri	*costatum*	Ari	*costatum*	Ari	*costatum*	Ari
dahaiense	Tri	*dahaiense*	Ari	*dahaiense*	Ari	*dahaiense*	Ari
elephas	Tri	*elephas*	Ari	*elephas*	Ari	*elephas*	Ari
rhombiforme	Tri	(*asperatum*)		(*elephas*)			
dilatatum	Tri	*dilatatum*	Ari	(*elephas*)			
handelii	Tri	*handelii*	Ari	*handelii*	Ari	*handelii*	Ari
intermedium	Tri	*intermedium*	Ari	*intermedium*	Ari	*intermedium*	Ari
lingyunense	Tri	*lingyunense*	Ari	*lingyunense*	Ari	*lingyunense*	Ari
parvum	Tri	*parvum*	Ari	*parvum*	Ari	*parvum*	Ari
nt		*pianmaense*	Ari	*pianmaense*	Ari	*pianmaense*	Ari
speciosum	Tri	*speciosum*	Ari	*speciosum*	Ari	*speciosum*	Ari
tengtsungense	Tri	*tengtsungense*	Ari	*tengtsungense*	Ari	*tengtsungense*	Ari
utile	Tri	*utile*	Ari	*utile*	Ari	*utile*	Ari
nt	Tri	*vexillatum*	Ari	*vexillatum*	Ari	*vexillatum*	Ari
wilsonii	Tri	*wilsonii*	Ari	*wilsonii*	Ari	*wilsonii*	Ari
**propinquum*	Tri	**propinquum*	Ari	nt			
austroyunnanense	Fim	**austroyunnanense*	*Ano	*austroyunnanense*	Fim	*austroyunnanense*	Att
nt		*menghaiense*	Cla	*lackneri*	Fim	*lackneri*	Att
penicillatum	Fim	*penicillatum*	Fim	*penicillatum*	Fim	*penicillatum*	Att
matsudae	Fim	(*penicillatum*)		(*penicillatum*)		(*penicillatum*)	
hunanense	Tor	*hunanense*	Cla	*hunanense*	Cla	*hunanense*	Cla
clavatum	Ari	*clavatum*	Cla	*clavatum*	Cla	*clavatum*	Cla
nt		*ilanense*	Cla	*ilanense*	Cla	*ilanense*	Cla
du-bois-reymondeae	Ari	*du-bois-reymondeae*	Cla	*silvestrii*	Cla	*silvestrii*	Cla
decipiens	Dec	*decipiens*	Dec	*decipiens*	Dec	*decipiens*	Dec
rhizomatum	Dec	*rhizomatum*	Dec	(*decipiens*)		(*decipiens*)	
flavum	Doc	*flavum* ssp. *tibeticum*	Doc	*flavum* ssp. *tibeticum*	Doc	*flavum* ssp. *tibeticum*	Doc
cordatum	Tor	*cordatum*	Fla	*cordatum*	Tor	*cordatum*	Fla
heterophyllum	Tor	*heterophyllum*	Tor	*heterophyllum*	Tor	*heterophyllum*	Fla
multisectum	Tor	(*heterophyllum*)		(*heterophyllum*)			
nt		*thunbergii* ssp. *autumnale*	Fla	*thunbergii* ssp. *autumnale*	Tor	*thunbergii* ssp. *autumnale*	Fla
sinii	Fra	*sinii*	Cla	*sinii*	Fim	*sinii*	Fra
candidissimum	Fra	*candidissimum*	Fra	*candidissimum*	Fra	*candidissimum*	Fra
fargesii	Fra	*fargesii*	Fra	*fargesii*	Fra	*fargesii*	Fra

TABLE 1. Continued

FRPS (1979)		Gusman & Gusman (2006)		FOC (2010)		Murata (2011)	
Species	Section	Species	Section	Species	Section	Species**	Section
franchetianum	Fra	*franchetianum*	Fra	*franchetianum*	Fra	*franchetianum*	Fra
delavayi	Fra	(*franchetianum*)		(*franchetianum*)			
lichangense	Fra	*lichangense*	Fra	*lichangense*	Fra	*lichangense*	Fra
auriculatum	Tor	*auriculatum*	Fla	*auriculatum*	Tor	*auriculatum*	Nep
hungyaense	Ten	*auriculatum* var. *hungyaense*	Fla	(*auriculatum*)			
meleagris	Ari	*meleagris*	Nep	*meleagris*	Nep	*meleagris*	Nep
shimienense	Ten	*shimienense*	Nep	(*meleagris*)		(*meleagris*)	
biauriculatum	Ari	*watii*	Nep	*watii*	Nep	*watii*	Nep
nepenthoides	Ari	*nepenthoides*	Nep	*nepenthoides*	Nep	*nepenthoides*	Nep
nt		*lidaense*	Att	*lidaense*	Fim	*lidaense*	Odo
aridum	Fra	*yunnanense* var. *aridum*	Att	*aridum*	Tor	*aridum*	Odo
saxatile	Tor	*saxatile*	Att	*mairei*	Tor	*mairei*	Odo
nt		*odoratum*	Att	*odoratum*	Tor	*odoratum*	Odo
bathycoleum	Att	*bathycoleum*	Att	*saxatile*	Tor	*saxatile*	Odo
prazeri	Att	*prazeri*	Att	*prazeri*	Tor	*prazeri*	Odo
nt		nt	Att	*quinquelobatum*	Tor	*quinquelobatum*	Odo
yunnanense	Att	*yunnanense* var. *yunnanese*	Att	*yunnanense*	Tor	*yunnanense*	Odo
lobatum	Pis	*lobatum*	Lob	*lobatum*	Pis	*lobatum*	Pis
onoticum	Pis	(*lobatum*)		(*lobatum*)			
amurense	Ari	*amurense*	Pis	*amurense*	Pis	*amurense*	Pis
sikokianum	Ari	*engleri*	Pis	*bockii*	Pis	*bockii*	Pis
angustatum var. *peninsulae*	Ari	*serratum*	Pis	*peninsulae*	Pis	*peninsulae*	Pis
ringens	Pis	*ringens*	Pis	*ringens*	Pis	*ringens*	Pis
arisanense	Pis	(*ringens*)		(*ringens*)			
taihokense	Pis	(*ringens*)		(*ringens*)			
nt		*xuanweiense*	Lob	*xuanweiense*	Pis	*xuanweiense*	Pis
japonicum	Ari	(*serratum*)		nt		nt	
serratum	Ari	*serratum*	Pis	nt		nt	
exappendiculatum	Ex	*exappendiculatum*	Sin	*exappendiculatum*	Sin	*exappendiculatum*	Sin
nt		*concinnum*	Sin	*concinnum*	Sin	*concinnum*	Sin
nt		*echinatum*	Sin	*echinatum*	Sin	*echinatum*	Sin
nt		*echinoides*	Sin	*echinoides*	Sin	*echinoides*	Sin
nt		*jingdongense*	Sin	*jingdongense*	Sin	*jingdongense*	Sin
nt		sp. *'Gaoligong'*	Sin	*muratae*	Sin	*muratae*	Sin
nt		*sukotaiense*	Sin	*sukotaiense*	Sin	*sukotaiense*	Sin
nt		*taiwanense*	Sin	*taiwanense*	Sin	*taiwanense*	Sin
nt		*zhui*	Sin	*zhui*	Sin	*zhui*	Sin
ciliatum	Sin	*ciliatum*	Sin	*ciliatum*	Sin	*ciliatum*	Sin
erubescens	Sin	*consanguineum*	Sin	*erubescens*	Sin	*consanguineum*	Sin
undulatum	Sin	(*consanguineum*)		(*erubescens*)			
kelung-insulare	Sin	*consanguineum* subsp. *keling-insularis*	Sin	(*erubescens*)			
biradiatifoliatum	Sin	(*consanguineum* subsp. *keling-insularis*)		(*erubescens*)			
formosanum	Sin	*formosanum*	Sin	(*erubescens*)			
oblanceolatum	Sin	(*formosanum*)		(*erubescens*)			
nt		*jinshajiangense*	Cla	*calcareum*	Fim	*calcareum*	Sin
jacquemontii	Ten	*jacquemontii*	Ten	*jacquemontii*	Ten	*jacquemontii*	Ten
brevispathum	Ten	(*jacquemontii*)					
souliei	Ten	*souliei*	Ten	*souliei*	Ten	*souliei*	Ten
wardii	Ten	*wardii*	Ten	*wardii*	Ten	*wardii*	Ten
tortuosum	Tor	*tortuosum*	Tor	*tortuosum*	Tor	*tortuosum*	Tor

fixed in 3:1 ethanol-acetic acid for 3 hours at 4°C, macerated with 1N HCl for 10 minutes at 60°C, then stained with Schiff's solution and squashed.

Molecular phylogeny: A molecular phylogenetic analysis was conducted based on the combined sequences of four chloroplast regions (3'*trnL–trnF*, *rpl20–5'rps12*, *psbB–psbH* and *rpoC2–rps2*). The sequence of *Arisaema aridum* H. Li was newly determined (DDBJ accession numbers: LC001792, LC001793, LC001794, LC001795) and used together with sequences of representative species cited in Ohi-Toma *et al.* (submitted) for the phylogenetic analysis. Multiple sequences were manually aligned by considering nucleotide changes and sequence motifs in the noncoding regions. Gap coding was employed using the criteria in Ohi-Toma *et al*. (2010). The coded gap-states were included as unweighted fifth characters in the matrix. Both nucleotide substitutions and coded gaps were used with equal weightings. To search for the shortest trees, maximum parsimony (MP) analysis was performed using branch and bound search using PAUP* version 4.0b10 (Swofford 2002). The strict consensus tree of the most parsimonious trees was generated, and character changes (substitutions and gaps) were reconstructed on the tree with ACCTRAN character optimization using PAUP* software. MP bootstrap support values were estimated using 1,000 replicates by branch and bound search.

Results and Discussion

1) ***Arisaema*** sect. ***Anomala*** Gusman & L. Gusman, Aroideana 26: 40 (2003).

In the FOC 11 species, *Arisaema petelotii* K.Krause, *A. smitinandii* S. Y. Hu, *A. menglaense* Y. H. Ji, H. Li & Z. F. Xu, *A. lihengianum* J. Murata & S. K. Wu, *A. victoriae* V. D. Nguyen, *A. pingbianense* H. Li, *A. rubrirhizomatum* H. Li & J. Murata, *A. grapsospadix* Hayata, *A. hainanense* C. Y. Wu ex H. Li, Y. Shiao & S. L. Tseng, *A. petiolulatum* Hook.f. and *A. bannaense* H. Li, were recognized in section *Anomala*. *Arisaema grapsospadix* and *A. hainanense* are endemic to Taiwan and Hainan, respectively. The other 9 species occur mainly in subtropical limestone areas around the southern border of China.

A new species *Arisaema rubrirhizomatum* was proposed to accommodate a species traditionally called "Red Root *Arisaema* [紅根南星]" in Chinese. Previously in *Flora Reipublicae Popularis Sinicae* (FRPS, Li 1979), *A. calcareum* was applied to represent the "Red Root *Arisaema*". In the protologue of *A. calcareum* H. Li in Li *et al.* (1977), carpellate and staminate inflorescences were described quite differently with corresponding illustrations. In comparison to the specimens in KUN, the carpellate illustration was based on one of a carpellate specimen (*Wang S.Z.* [王守正]*712*, KUN) that is very similar to the type specimen (*Local Botanical Group s.n.* 1964. 6. 5. KUN, carpellate) and the staminate illustration was based on a staminate specimen (*Wu Q.A.* [武全安]*7905*, KUN). After careful examination of these specimens, the first author (JM) noticed that the carpellate specimen is identical with *Arisaema jinshajiangense* H. Li and the staminate specimen is identical with *A. petelotii* K. Krause. This suggests that the sexually dimorphic nature of *A. calcareum* was an imaginary characteristic. Since *A. calcareum* is conspecific with *A. jinshajiangense* H. Li, based on the identity of the type specimen, the correct name for this species is *A. calcareum* and *A. jinshajiangense* is to be reduced to synonymy. Consequently, the Chinese "Red Root *Arisaema*" was described as a new species, *A. rubrirhizomatum* H. Li & J. Murata (Fig 1) in the FOC. Although close relationship to sect. *Sinarisaema* was indicated by a molecular phylogenetic analysis (Renner *et al.* 2004), *A. calcareum* was placed in sect. *Clavata* [in Gusman & Gusman (2006, as *A. jinshajiangense*)] or in sect. *Attenuata* in the FOC.

2) ***A.*** sect. ***Attenuata*** (Engl.) H. Li, Fl. Reipubl. Popularis Sin. 13(2): 127 (1979) .

= Sect. *Fimbriata* (Engl.) H. Li, Fl. Reipubl. Popularis Sin. 13(2): 123 (1979).

From the molecular phylogeny of Renner *et al.* (2004), sect. *Tortuosa* (Engl.) Nakai of traditional circumscription was shown to be polyphyletic. Based on the molecular phylogeny Gusman and Gusman (2006) distinguished sect. *Attenuata* from sect. *Tortuosa* and recognized *Arisaema prazeri* Hook.f. as the type species. However, sect. *Attenuata* (Engl.) H. Li was already lectotypified with *A. laminatum* Blume by Hara (1971). As *A. laminatum* clearly belongs to sect. *Fimbriata*, sect. *Attenuata* and sect. *Fimbriata* are considered to be synonymous.

Sections *Attenuata* and *Fimbriata* were legitimately published in the same publication (Li 1979). In the FOC, section *Attenuata* was ignored and section *Fimbriata* was adopted. When section *Fimbriata* was treated as a synonym of section *Attenuata* for the first time in Murata *et al.* (2013), the priority of sect. *Attenuata* over section *Fimbriata* was established [*International Code of Nomenclature for algae, fungi and plants* (*Melbourne Code*) 2011, Art. 11.5 note 3]. A similar treatment in Murata (2011) was not effective because the combination cited, sect. *Attenuata* (Engl.) Hara, was invalid.

In the FOC six species, *Arisaema austroyunnanense* H. Li, *A. calcareum*, *A. lackneri* Engl., *A. lidaense* J. Murata & S. K. Wu, *A. penicillatum* N. E. Br. and *A. sinii* K. Krause, are recognized in sect. *Attenuata*.

In considering molecular phylogeny (Fig. 2), Murata (2011) moved *Arisaema lidaense* to section *Odorata* and *A. sinii* to section *Franchetiana*. As discussed above, the name *A. calcareum* was applied for *A. jinshajianense* for the first time in the FOC. Although *A. calcareum* was still placed in sect. *Attenuata* in the FOC (as sect. *Fimbriata*), according to molecular phylogenies (Renner *et al.* 2004, Ohi-Toma *et al.* submitted) *A. calcareum* should be moved to sect. *Sinarisaema*.

It is remarkable that *Arisaema lackneri* was recently re-discovered (as *A. menghaiense* J. T. Yin, H. Li & Z. F. Xu) in China (Yin *et al.* 2004). The systematic position of *A. lackneri* is still uncertain. A molecular phylogeny including *A. lackneri* is needed.

3) ***A.*** sect. ***Tortuosa*** (Engl.) Nakai, Bot. Mag. (Tokyo) 43: 524 (1929).

In the FOC, 12 species were recognized in sect. *Tortuosa*. In Murata (2011), based on molecular phylogenies (Renner et al. 2004, Ohi-Toma *et al.* submitted, and Fig. 2), *Arisaema aridum* H. Li, *A. mairei* Engl., *A. odoratum* J. Murata & S. K. Wu, *A. prazeri* Hook.f., *A. quinquelobatum* H. Li & J. Murata, *A. saxatile* Buchet and *A. yunnanense* Buchet were separated to form section *Odorata*: *A. cordatum* N. E. Br., *A. heterophyllum* Blume and *A. thunbergii* Blume were separated to form section *Flagellarisaema* and *A. auriculatum* Buchet was moved to section *Nepenthoidea*. Consequently, *A. tortuosum* (Wall.) Schott, is the only Chinese element in this section (Table 1). The main distribution range of *A. tortuosum* is India and the Himalayan region. Although Tibet, Yunnan and Sichuan are indicated in the FOC as the distribution range of *A. tortuosum* in China, specimens are rarely collected.

4) ***A.*** sect. ***Tenuipistillata*** (Engl.) H. Hara, Univ. Mus. Univ. Tokyo. Bull. 2: 346 (1971).

In the FOC three species, *Arisaema jacquemontii* Blume, *A. wardii* C. Marquand & Airy Shaw and *A. souliei* Buchet, were recognized. *A. jacquemontii* has a wide distribution, mainly in the Himalayan region, and widely overlaps with *A. flavum* (Forsk.) Schott subsp. *abbreviatum* (Schott) J. Murata. The other two species are endemic to China.

5) ***A.*** sect. ***Dochafa*** (Schott) H. Hara, Univ. Mus. Univ. Tokyo. Bull. 2: 344 (1971).

Section *Dochafa* is monotypic, represented by *Arisaema flavum*. Of the three subspecies of *A. flavum* recognized by Murata (1990a), subsp. *tibeticum* J. Murata is distinct in being diploid ($2n = 28$), producing a staminate spadix in smaller individuals (the other two subspecies lack a staminate stage), and in the spathe secreting nectar on the ventral surface.

6) ***A.*** sect. ***Odorata*** J. Murata ex J. Murata, J. Jap. Bot. 88: 43 (2013).

Section *Odorata* was separated from sect. *Tortuosa* by Gusman and Gusman (2006) as "sect. *Attenuata*" [previously recognized as "subsect. *Attenuata*" in Gusman & Gusman (2002)].

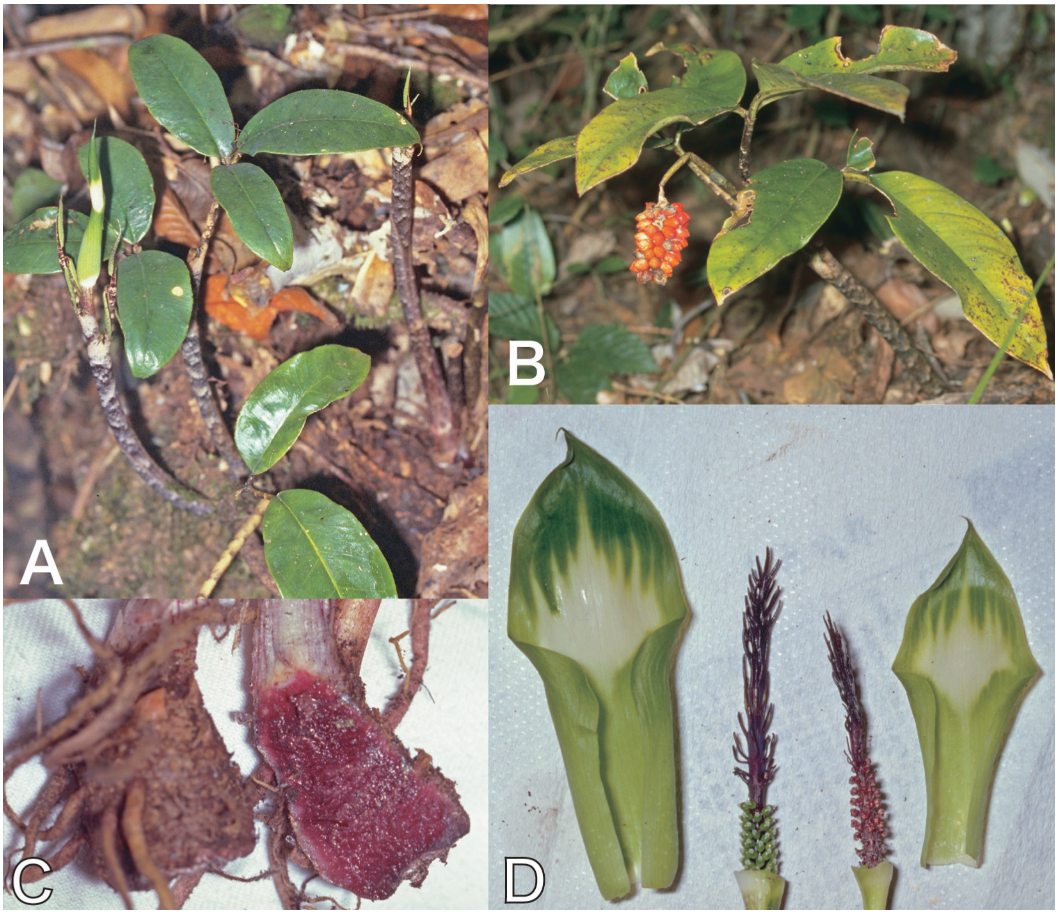

FIG. 1. *Arisaema rubrirhizomatum* (sect. *Anomala*) (in Malipo, S. Yunnan, Feb. 22, 1994). A: New flowering shoots with folded spathe and leaves arising by the old leaf. B: Fruiting individual with three trifoliolate leaves. C: Rhizome cut open to show reddish purple inside. D: Carpellate (left) and staminate (right) inflorescences, spathe removed.

Because sect. *Attenuata* is not applicable to this group, as discussed above, a new section *odorata* J. Murata was proposed (Murata 2011) and validly published (Murata *et al*. 2013).

In the FOC most species of sect. *Odorata* were placed in sect. *Tortuosa* (Table 1). Based on a molecular phylogeny (Fig. 2) *Arisaema lidaense* was moved to section *Odorata* from sect. *Fimbriata* and, consequently, sect. *Odorata* consists of 8 species (Murata 2011). The important characters and geographical distribution of the species are summarized in Table 2. It is notable that the chromosome numbers are quite differentiated in this group.

Arisaema prazeri, the oldest name within sect. *Odorata*, is the species most widely distributed in subtropical regions. Its chromosome number, $2n = 26$, is unique in this group.

Arisaema lidaense is another subtropical species known only from limestone areas in southern Yunnan. It shares a monoecious spadix with *A. odoratum* J. Murata & S. K. Wu, but is distinct in the color of the spathe and the shape of spadix appendage. The chromosome number is $2n = 24$.

Arisaema yunnanense is the second oldest named species in sect. *Odorata*. It has trifoliolate leaves and a slender, short spadix appendage. It is common in Yunnan and adjacent Sichuan and

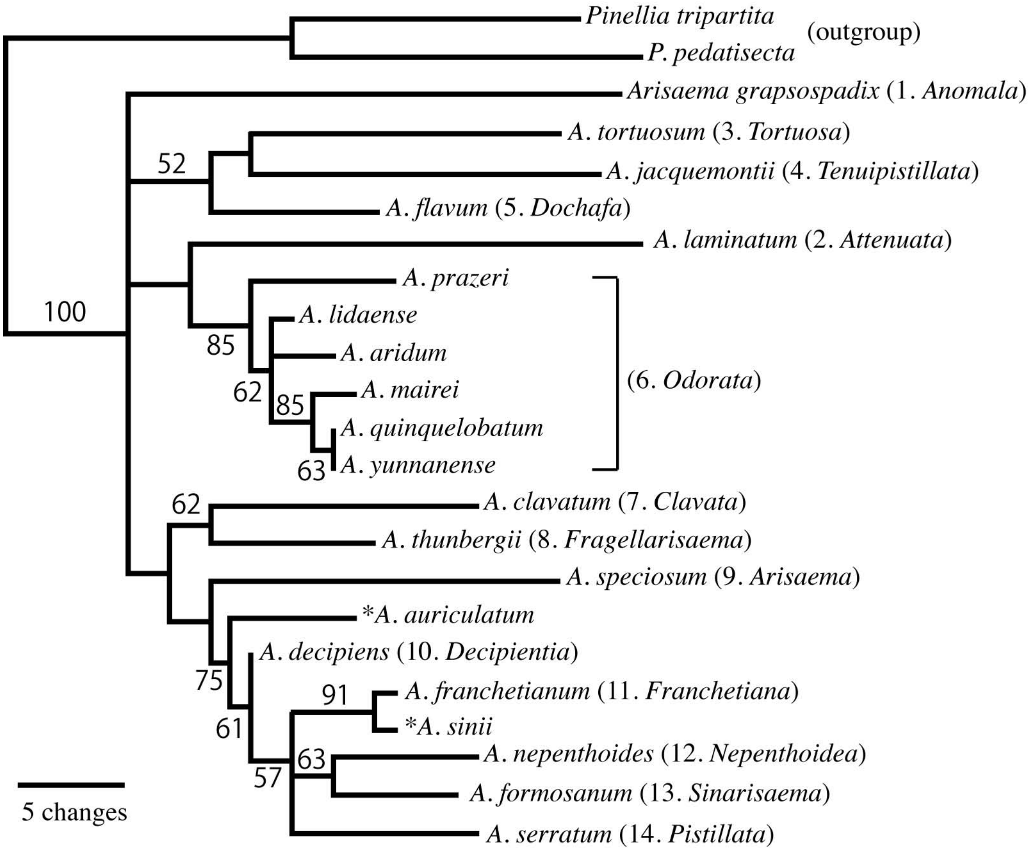
Pinellia tripartita
P. pedatisecta
(outgroup)
Arisaema grapsospadix (1. Anomala)
A. tortuosum (3. Tortuosa)
A. jacquemontii (4. Tenuipistillata)
A. flavum (5. Dochafa)
A. laminatum (2. Attenuata)
A. prazeri
A. lidaense
A. aridum
A. mairei
A. quinquelobatum
A. yunnanense
(6. Odorata)
A. clavatum (7. Clavata)
A. thunbergii (8. Fragellarisaema)
A. speciosum (9. Arisaema)
*A. auriculatum
A. decipiens (10. Decipientia)
A. franchetianum (11. Franchetiana)
*A. sinii
A. nepenthoides (12. Nepenthoidea)
A. formosanum (13. Sinarisaema)
A. serratum (14. Pistillata)
100
52
85
62
85
63
62
75
61
91
63
57
5 changes

FIG. 2. Molecular phylogenetic tree of *Arisaema*, showing monophyly of sect. *Odorata*. Sectional affiliation of the species (mostly type species) is indicated in parentheses. The position of *A. auriculatum* and *A. sinii* (with an asterisk) is discussed in the text. This is the strict consensus tree of the 15 most parsimonious trees based on the combined sequences of four chloroplast regions, 3'*trnL–trnF, rpl20–5'rps12, psbB–psbH*, and *rpoC2–rps2* (length = 249, CI = 0.84, RC = 0.62). Branch lengths were estimated based on ACCTRAN character optimization using PAUP, scale bar (five site changes) is shown. Support values of branches (>50%) estimated using bootstrap analysis are shown by the branches.

Guizhou and shows remarkable morphological variation. The chromosome number of 2*n* = 48 in *Arisaema yunnanense* is unique in *Arisaema*.

In NW Yunnan a species with an inflorescence similar to *Arisaema yunnanense*, but with five foliolate leaves was observed (Fig. 3D). Gusman & Gusman (2006: 160) show a photograph of this species as *A. saxatile*. The chromosome number of 2*n* = 24 (Murata *et al*. 2006, as five-foliolate *A. yunnanense*) suggests that these plants, described as *A. quinquelobatum* H. Li & J. Murata in the FOC, is diploid and *A. yunnanense* is a closely related tetraploid species. A molecular phylogeny supports this hypothesis (Fig. 2).

Arisaema mairei Engl. was described as having pedate leaves and a white spathe. The conspecific *A. wumengense* H. Li also has these characteristics. *Arisaema odoratum*, a sister species of *A. mairei* in the molecular phylogeny (Fig. 2), shares the white spathe and fragrant whip-like spadix appendage with *A. mairei* but differs in the monoecious spadix and trifoliolate leaves. These two species also share a chromosome number of 2*n* = 22, which is unique in *Arisaema*.

The type specimens of *Arisaema aridum* H. Li has a 5-foliolate leaf, a staminate spadix and a

TABLE 2. A summary of the species of *Arisaema* sect. *Odorata*. Distinct character states are shaded in each species.

Species	***A. saxatile*** Buchet (1911)	***A. prazeri*** Hook.f. (1893)	***A. lidaense*** J. Murata & S. K. Wu (2003)	***A. quinquelobatum*** H. Li & J. Murata (2010)	***A. yunnanense*** Buchet (1911)	***A. odoratum*** J. Murata & S. K. Wu (1994)	***A. mairei*** H. Lév. (1915)	***A. aridum*** H. Li (1977)
Synonym	*A. bathycoleum* Hand.-Mazz. (1925), *A. lineare* Buchet (1911)				*A. taliense* Engl. (1920), *A.* taliense var. *latisectum* Engl. (1920) *A. trifoliolatum* Gagnep.		*A. maireanum* Engl. (1920), *A. wumengense* H. Li, Q. T. Zhang & L. S. Xie (2000)	
Misapplied name				*A. aridum* (Lenner *et al*. 2004); *A. saxatile* (Gusman & Gusman 2006, partly)			*A. saxatile* (Lenner *et al*. 2004; Gusman & Gusman 2002, 2006)	*A. saxatile* (Li 1979), *A. yunnanese* var. *aridum* (Gusman & Gusman 2002, 2006)
Chromosome number $2n$ =	?	26	24	24	48	22	22	16
Leaflet number and arrangement	3 (–5)	3	3	Radiately 5	3	3	Pedately more than 5	Pedately more than 5
Spathe color	green	green	green	green	green	white	white	green
Fragrance	none	none	none	none	none	distinct	distinct	none
Sex expression in mature inflorescence	Female	Monoecious	Monoecious	Female	Female	Monoecious	Female	Female
Ovary shape	spindle shaped	bottle shaped	bottle shaped	bottle shaped	bottle shaped	bottle shaped	bottle shaped	bottle shaped
Spadix appendage	long	long	short	short	short	long	long	long
Distribution	W Yunnan to W Sichuan	S & SW Yunnnan, Myanmar –Thailand	S Yunnan	NW Yunnan	Yunnan, W Sichuan, W Guizhou, Myanmar	Central N Yunnan	Central Yunnan to central S Sichuan	NW Yunnan

slender elongate spadix appendage (Li *et al.* 1977: plate 9-4). In the FRPS (Li 1979) a more detailed description and an illustration, probably based on the type specimen, was provided, but the carpellate inflorescence was not described. Field observations on the bank of the Jinsha Jiang at Tiger Leaping Gorge in NW Yunnan, A. *aridum* shows a wide range of variation in size and morphology. Small plants with a staminate inflorescence usually have a single leaf with five, pedately or nearly radiately arranged leaflets (fig. 3A, 3B) and agree well with the descriptions and illustrations by Li *et al.* (1977) and Li (1979). Larger plants with a carpellate inflorescence usually have two leaves with more than seven, pedately arranged leaflets (fig. 3B). Although the larger plants are rather similar to *A. tortuosum* or *A. heterophyllum*, it appears to be species of section *Odorata* (Fig. 2). In this study *A. aridum* was revealed to have the lowest chromosome number in *Arisaema* $2n = 16$ (previously $2n = 20$ in *A. costatum* was lowest) (Fig. 4).

Arisaema bathycoleum Hand.-Mazz. is similar to *A. yunnanense* and they "always grow together" (Li 1979), but it is readily distinguished by the slender leaflets and long, filiform spadix appendage, although slender leaflets rarely occur in *A. yunnanense* Buchet (Fig. 3c). *Arisaema yunnanense* with slender leaflets was also shown in Gusman & Gusman (2002: 369) as *A. bathycoleum*. In *A. yunnanense* the carpellate peduncle is usually much longer than the petiole and the bottle shaped ovaries are tightly congested. In *A. bathycoleum* the carpellate peduncle is usually shorter (longer in staminate) than the petiole and the ovaries are spindle shaped and rather loosely arranged. The chromosome number and molecular phylogenetic position of *A. bathycoleum* has not been examined.

Arisaema saxatile Buchet and *A. lineare* Buchet were described at the same time in the same publication (Buchet 1911). Type specimens of both species were collected between Dali and Lijiang in NW Yunnan. The type sheet of *A. saxatile* contains two carpellate individuals both with a single five-foliolate leaf (but described as 5–7-foliolate) and a short peduncle. The type specimen of *A. lineare* consists of a staminate individual with two leaves having three and five leaflets each and a long peduncle. In other characteristics such as the narrow sessile leaflets and filiform spadix appendage, they are similar. In considering sexual dimorphism in the length of the peduncle in *A. bathycoleum*, these two species may be conspecific. Their identity has been considered variously (Table 2). Li (1979) recognized them as two independent species. In Gusman & Gusman (2002, 2006), *A. saxatile* (the spathe is mentioned as yellow in the protologue) was considered to be conspecific with *A. mairei* with a white spathe. *Arisaema mairei* and *A. lineare* was treated as synonyms of *A. saxatile*, which established the nomenclatural priority of *A. saxatile* over *A. lineare*. In the FOC *A. saxatile* (= *A. lineare*) was considered to be an unusual five-foliolate form of *A. bathycoleum*, based on the similarity of their inflorescence and slender leaflets. Cytological and molecular phylogenetic information as well as field observations of *A. bathycoleum* will help to determine the circumscription of these species.

7) ***A.*** sect. ***Clavata*** (Engl.) H. Ohashi & J. Murata, J. Fac. Sci. Univ. Tokyo, Sect. III 12: 283 (1980).

In the FOC, *Arisaema clavatum* Buchet, *A. hunanense* Hand.-Mazz., *A. ilanense* J. C. Wang and *A. silvestri* Pampan. (= *A. dubois-reymondiae* Engl.) were recognized as belonging to section Clavata. *Arisaema ilanense*, which is similar to *A. heterocephalum* Koidz. of the Ryukyu Islands, Japan, was found in Taiwan recently (Wang 1996). *Arisaema hunanense* is similar to another Japanese species, *A. negishii* Makino, of the Izu Islands.

8) ***A.*** sect. ***Flagellarisaema*** (Nakai) H. Hara, Univ. Mus. Univ. Tokyo. Bull. 2: 326 (1971).

In the FOC this section was included in section *Tortuosa* and three species, *Arisaema cordatum*, *A. heterophyllum* and *A. thunbergii* subsp. *autumnale* J. C. Wang, J. Murata & H. Ohashi were placed there.

Arisaema cordatum is endemic to Hong Kong

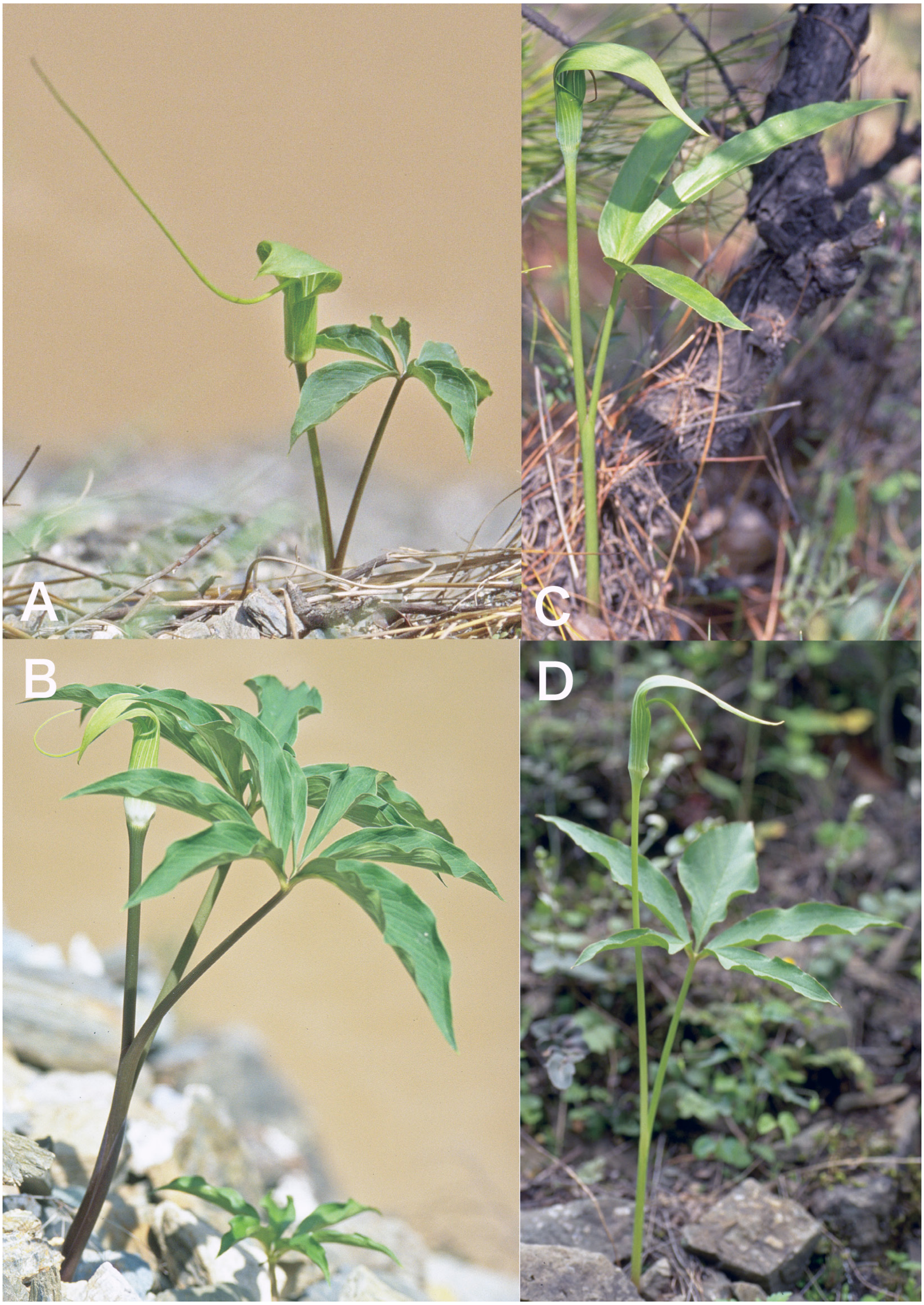

FIG. 3. Species of *Arisaema* sect. *Odorata* in NW Yunnan. A, B: *A. aridum* (in Tiger Leaping Gorge). C: *A. yunnanense* with slender leaflets (in Lijiang). D: *A. quinquelobatum* (in Tiger Leaping Gorge).

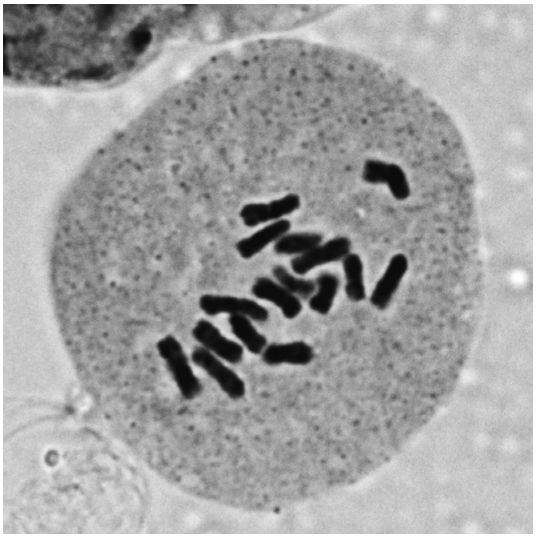

FIG. 4. Somatic chromosomes of *Arisaema aridum*, 2*n* =16 (J. Murata 950623).

and was reported to be related to the Japanese *A. kiushianum* by Gusman & Gusman (2006) based on the simple, cordate plumular leaf (referred as an eophyll). Although Gusman & Gusman (2006) commented that the leaflets are "often erect when unfolding as usual in *Typhonium*," but are folded downward in the bud (http://www.srgc.net/forum/index.php?topic=6568.15) as in other species of section *Flagellarisaema*. The difference in the aestivation of the pedate leaves of *Arisaema* and *Typhonium* was discussed in Murata (1990d).

9) *A.* sect. *Arisaema*

In the FOC 16 species were recognized in section *Arisaema*. Of them, *A. costatum* (Wall.) Mart. ex Schott, *A. intermedium* Blume, *A. speciosum* (Wall.) Mart. ex Schott, *A. utile* ex Schott and *A. vexillatum* H. Hara & H. Ohashi are Himalayan elements and are rarely found in adjacent southern Tibet.

The circumscription of *A. asperatum* N. E. Br., *A. bonatianum* Engl. and allies was revised by Murata (1990c), who considered that asperate trichomes might not be stable within a species. In the FOC, however, *A. brucei* H. Li & J. Murata was separated from *A. asperatum* based on the smooth surface of the petiole and peduncle.

Arisaema dahaiense H. Li was described based on cultivated material from NW Yunnan, Huize Xian, Dahai, as the type specimen. Li *et al.* (1999) noted, however, that the type locality might be erroneous and the distribution in NE Yunnan might be incorrect. Instead, Li *et al.* (1999) cited specimens of *A. dahaiense* from W. Yunnan. Actually, *A. dahaiense* is identical with *A. dulongense* H. Li (Li 1992) from the Dulong Jiang region, NW Yunnan. *A. dahaiense* is characteristic in having a rhizome, a spathe that lacks lamellae on the ventral surface and has a galeate limb and a long thread-like spadix appendage. In the former two characters as well as in the chromosome number, 2*n* = 26 (Murata 1990b, Gu *et al*. 1992, as *A. dulongense*), *A. dahaiense* is similar and considered to be close to the Himalayan *A. galeatum* N. E. Br.

In our recent expeditions to Myanmar a species similar to *A. dahaiense*, but with a tuberous underground stem, was found in higher places on Natmataung (Victoria Peak) in W. Myanmar (Fig. 5A). These plants may be *A. lingyunense* H. Li, which was published in the same publication as *A. dahaiense*. In the protologue, *A. lingyunense* was briefly described, but paratype specimens from Guangxi (*Steward & Cheo 188*, A! NY!) (Fig. 5B) clearly show a subglobose tuber and a large galeate spathe similar to *A. dahaiense*.

Six additional species, *Arisaema elephas* Buchet, *A. wilsonii* Engl., *A. handelii* Stapf ex Hand.-Mazz., *A. parvum* N. E. Br. ex Hemsl., *A. pianmaense* H. Li and *A. tengtsungense* H. Li, as well as *A. asperatum*, *A. bonatianum* and *A. dahaiense*, are endemic to China. *Arisaema elephas* is the most widely distributed and commonest, and also the morphologically most variable species. *Arisaema handelii* is characteristic in having a thick, verrucose spadix appendage (Fig. 5C, 5D) but the distinctness of the other species has not been ascertained.

10) *A.* sect. *Decipientia* (Engl.) H. Li, Fl. Reipubl. Popularis Sin. 13(2): 166 (1979).

In the FRPS, two species, *Arisaema decipiens*

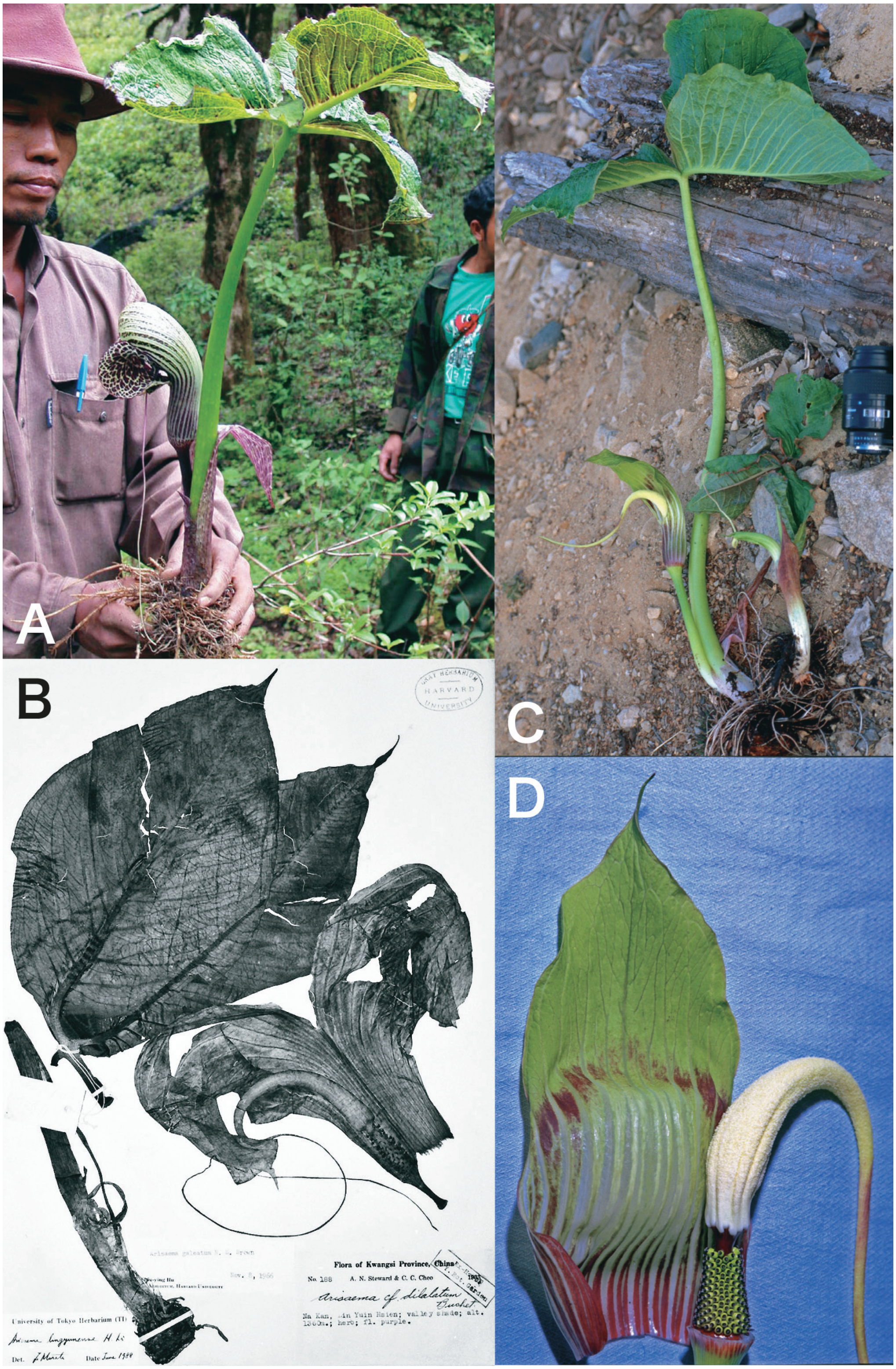
A
B
HARVARD UNIVERSITY
Arisaema galeatum N. E. Brown
Nov. 8, 1966
Shiu-ying Hu
Arboretum, Harvard University
Flora of Kwangsi Province, China
No. 188 A. N. Steward & C. C. Cheo
1933
Y. Bot. Garden
Arisaema cf. dilalatum Buchet
Na Kan, Lin Yuin Hsien; valley shade; alt. 1360m.; herb; fl. purple.
University of Tokyo Herbarium (TI)
Arisaema lingyunense H. Li
Det. J. Murata Date June 1988
C
D

FIG. 5. Species of *Arisaema* sect. *Arisaema*. A: *A. lingyunense* (Natumataung, Myanmar). B: *A. lingyunense* (Steward & Cheo 188, A). C, D: *A. handelii* (in Xinzhu, NW Yunnan).

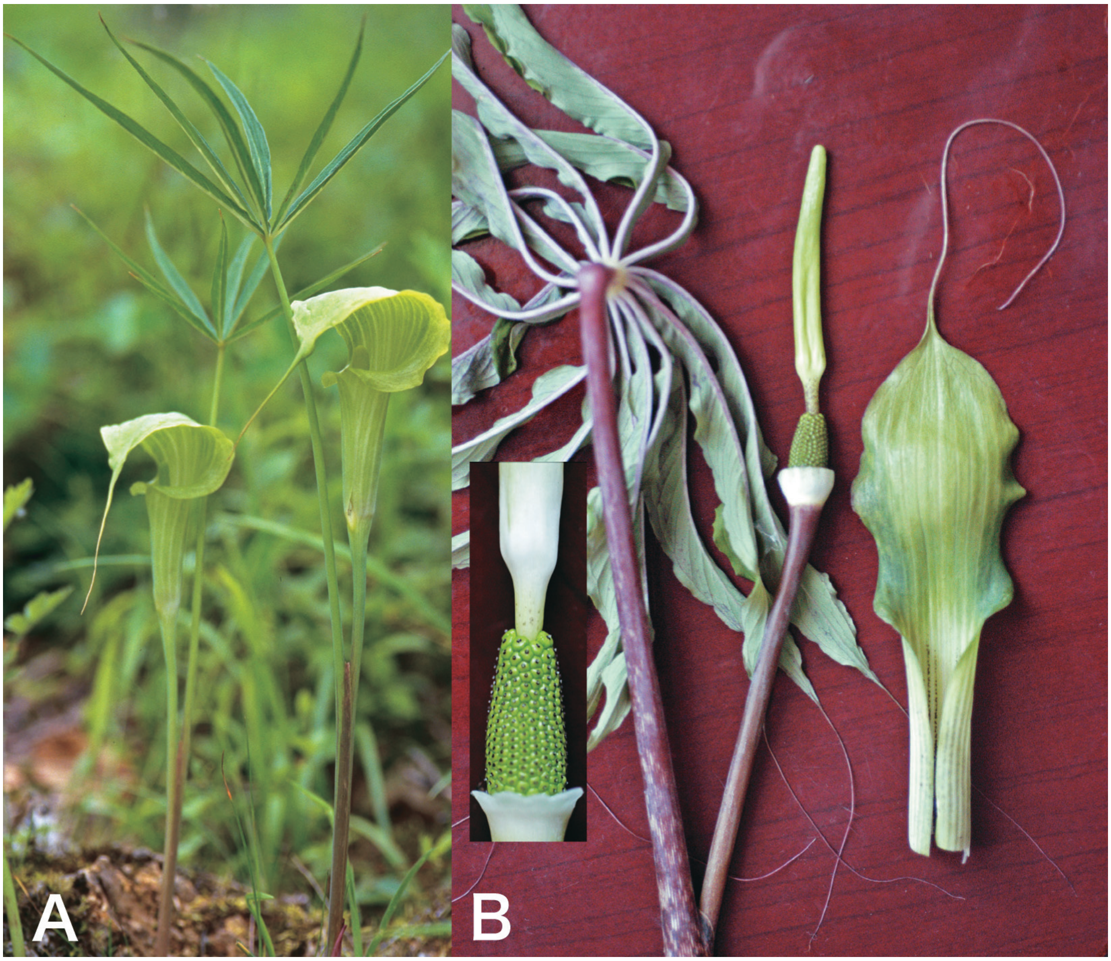

FIG. 6. Species of *Arisaema* sect. *Sinarisaema* found in Lijiang, NW Yunnan. A: *A. linearifolium*. B: *A. wangmoense*.

Schott described from India and *A. rhizomatum* C. E. C. Fischer described from China, were placed in section *Decipientia*. They are distinguishable only in the shape of the spadix appendage. According to our field observations and literature reports, the color and shape of the inflorescence in *A. rhizomatum* shows wide variation and the shape of the spadix appendage is sometimes deformed in dried herbarium specimen. In the FOC, therefore, *A. rhizomatum*, together with *A. guixiense* S. Y. Liu, was synonymized under *A. decipiens*.

11) ***A.*** sect. ***Franchetiana*** (Engl.) H. Hara, Univ. Mus. Univ. Tokyo Bull. 2: 326 (1971).

In the FOC, four species, *Arisaema candidissimum* W. W. Smith, *A. fargesii* Buchet, *A. franchetianum* Engl. and *A. lichangense* W. W. Smith, were recognized in section *Franchetiana*. Our molecular phylogeny (Fig. 2) shows that *A. sinii* forms a monophyletic clade with other members of sect. *Franchetiana* and should also be included in this section. Because of a combination of characters, i.e. trifoliolate leaves and sterile flowers above the fertile flowers, *A. sinii* has been placed in sect. *Franchetiana* (Li 1979, Murata 2011), sect. *Clavata* (Gusman & Gusman 2002, 2006), or in sect. *Attenuata* (as sect. *Fimbriata*) in the FOC.

12) ***A.*** sect. ***Nepenthoidea*** (Engl.) Gusman & L. Gusman ex J. Murata, *Arisaema* in Japan: 63 (2011).

In the FOC, three species, *Arisaema meleagris* Buchet, *A. nepenthoides* (Wall.) Mart. ex Schott and *A. wattii* Hook.f., were included in section *Nepenthoidea*. In these three species the number of leaflets varies from three to more than seven, but the inflorescence is similar in all of them: the spathe opens much earlier than the leaves and the spathe is commonly brownish olive-green mottled or dotted with pink, purple and brown. *Arisaema shimienense*, *A. paichuanense* Z. Y. Zhu and *A. pangii* H. Li described from China also share this type of inflorescence. Although Gusman & Gusman (2006) recognized *A. shimienense* as an independent species and synonymized *A. pangii* (1992) under *A. nepenthoides*, and *A. paichuanense* (1983) under *A. meleagris*, we recognize all of them as representing the range of variation within the single species, *A. meleagris*.

In Murata (2011), *Arisaema auriculatum* Buchet was also placed in sect. *Nepenthoidea*. Previously it was placed in sect. *Flagellarisaema* in FRPS or sect. *Tortuosa* in the FOC. Gusman & Gusman (2006) placed it in sect. *Flagellarisaema*. However, in our molecular phylogeny (Fig. 2) *A. auriculatum* does not belong to the Tortuosa clade or the Fragellarisaema clade. Although it appeared to be sister to *A. clavatum* (sect. *Clavata*) in Renner *et al*. (2004), the material seemed to be misidentified. Morphologically, *A. auriculatum* shares such characteristics with *A. meleagris* as the brownish olive-green and pink, purple and brown mottled spathe that opens earlier than the leaf, frequently sinuate leaflets and underground stolons, although there is a sharp distinction in the shape of the spadix appendage. Murata (2011) and Murata *et al*. (2013) therefore placed *A. auriculatum* in sect. *Nepenthoidea* provisionally. *Arisaema lushuiense* G. W. Hu & H. Li, somewhat intermediate between *A. meleagris* and *A. auriculatum*, should also be included in sect. *Nepenthoidea*.

13) ***A.*** sect. ***Sinarisaema*** Nakai, J. Jap. Bot. 25(1): 6 (1950).

In the FOC 11 species, *Arisaema echinatum* (Wall.) Schott, *A. echinoides* H. Li, *A. erubescens* (Wall.) Schott, *A. exappendiculatum* Hara, *A. ciliatum* H. Li, *A. concinnum* Schott, *A. jingdongense* H. Peng & H. Li, *A. muratae* Gusman & J. T. Yin, *A. sukotaiense* Gagnep., *A. taiwanense* J. Murata and *A. zhui* H. Li, were recognized in this section. Of them, *A. echinatum*, *A. concinnum*, *A. erubescens* and *A. exappendiculatum* are Himalayan elements and are rarely found (if at all) in China. *A. taiwanense* is endemic to Taiwan. *A. sukotaiense* is mainly distributed in Indo-China, but is frequent in southern Guangxi and Yunnan.

Sect. *Sinarisaema* is diverse in China and there are many characteristic local populations. Some of them have been described as *A. ciliatum*, *A. echinoides*, *A. jingdongense*, *A. linearifolium* Gusman & J. T. Yin, *A. muratae*, and *A. zhui*, but still many populations are expected to be undescribed. For example, photographs identified as *A. erubescens* in Shui & Chen (2006: 203) are a mixture of *A. sukotaiense* with green spathe (no. 556e & f) and an undescribed species (no. 656a-d).

In national and local floras of China, the commonest species of section *Sinarisaema* has been referred to as *Arisaema erubescens*. As was noted in the FOC, however, the first author (JM) considers that true *A. erubescens* is restricted to the higher Himalayan region and the Chinese species is *A. consanguineum*. To distinguish these two species, Hara (1971) suggested that *A. erubescens* has a stipitate spadix appendage and an upright infructescence while *A. consanguineum* has a sessile spadix appendage with sterile flowers at the base and a nodding infructescence. It is also evident that the inflorescence opens much earlier than the leaf in *A. erubescens* but much later in *A. consanguineum*. Adding to the confusion are several undescribed species in China. *Arisaema wangmoense* M. T. An, H. H. Zhang & Q. Lin, which was described after publication of the FOC, was one of those species, where the spadix appendage is clearly stipitate and no sterile flowers occur at the base (fig. 6) as in *A. erubescens*.

Arisaema calcareum, which is treated here in sect. *Sinarisaema* based on molecular phylogeny, shares the sessile spadix appendage bearing sterile flowers on it with other members of this section, but the trifoliolate leaves are not harmonious. A spirodistichous phyllotaxy, one of the synapomorphies of this section, is expected to occur in *A. calcareum*.

14) ***A.*** sect. ***Pistillata*** (Engl.) Nakai, Bot. Mag. (Tokyo) 43: 525 (1929).

=*Arisaema* sect. *Lobata* Gusman & L. Gusman, [Gen. *Arisaema*: 215 (2002), nom. nud.] Gen. *Arisaema*, ed. 2: 260 (259) (2006).

In the FOC, six species, *Arisaema xuanweiense* H. Li, *A. lobatum* Engl., *A. ringens* (Thunb.) Schott and *A. amurense* Maxim., *A. bockii* Engl. and *A. peninsulae* Nakai were recognized in this section.

Arisaema amurense [= *A. sachalinense* (Miyabe & Kudo) J. Murata], *A. peninsulae* and *A. ringens* are in NW China or on the Pacific seacoast and also in Japan. *Arisaema bockii* is also in E China and is sometimes referred to *A. sikokianum* or *A. sazensoo* distributed in Japan, but is distinct at least in the chromosome number of $2n = 26$ from the two Japanese species with $2n = 28$ (Murata *et al*. 2006).

Arisaema lobatum is occurs widely, but is endemic to China. Gusman & Gusman (2002) proposed the monotypic section *Lobata* and published it in Gusman & Gusman (2006) based on the nodding infructescence. Gusman & Gusman (2006) included *Arisaema xuanweiense*, known only from the type specimen with a carpellate spadix, in sect. *Lobata*.

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